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LCA OF BOOKS

Books from an environmental perspective—Part 1: environmental impacts of paper books sold in traditional and internet bookshops

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Abstract
Purpose The sale and distribution of books are activities that have changed through increased use of the internet. The main aim of this paper was to determine the potential environmental impacts of paper books and identify key issues determining the magnitude of those impacts. A second aim was to study the environmental difference between a paper book bought in a traditional bookshop and through an internet bookshop. In addition, areas with a lack of data and major uncertainties were to be noted.
Materials and methods A screening life cycle assessment was performed on an average hardback novel produced and read in Sweden. The data used were general data from Ecoinvent 2.0 and site-specific data from companies participating in the study, whenever average data were not available.
Results and discussion The results showed the most important processes to be pulp and paper production. However, if a substantial distance was travelled by car, to buy a book or collect it, this had a major influence on the environmental performance. Comparing the two bookshop alternatives, the results showed a slight benefit for the internet bookshop due to fewer books being returned to the publisher and the avoidance of energy use at the traditional bookshop. The buyer of a book could significantly influence the total impact by choosing to walk to the bookshop or to combine the trip with several other activities to decrease the impact of the travel per activity performed. When books ordered via the internet were sent by postal services directly to the end consumer, the climate change impact was lowered.
Conclusions This study showed that, in addition to the paper used, the way books are bought and distributed, including possible personal transportation, can significantly affect the total environmental impact of paper books. The impact per book read can be significantly decreased by sharing books with others.

Keywords Book · Distribution · E-commerce · Internet · Printed media

Preamble Developments in information and communication technology (ICT) are providing new solutions in different fields of society. The conditions for the media sector are changing and ICT is part of the reason for this. Traditional ways of providing and consuming media content are being complemented or challenged by electronic alternatives. This study examined the potential environmental impact of books, comparing traditional paper books sold in traditional bookshops, traditional paper books sold via internet bookshops and e-books sold via internet books stores and read on an e-book reader. The results of the screening LCA are presented in two papers, the first focusing on paper books from traditional and internet bookshops and the second on the e-book compared with the paper book.

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1 Introduction

Developments in information and communication technology (ICT) are providing new solutions in different fields of society. The conditions for the media sector are changing and ICT is part of the reason for this. Traditional ways of providing and consuming media content are being complemented or challenged by electronic alternatives. With the introduction of the internet and the increasing amount of services provided electronically, discussions continue on the possible environmental benefits that could be gained.

Berkhout and Hertin (2004) draw the general conclusion that digital solutions may be both positive and negative from an environmental point of view. The seller–buyer relationship is one area where the internet may provide improvements, according to Berkhout and Hertin (2004), as goods may be produced in more direct response to customer demands, which could lead to reduced energy demand for warehousing.

Previous studies on the environmental impacts of scholarly books compared paper books with electronic versions read on computers (Enroth 2009) and on e-readers (Kozak 2003). Kozak (2003) studied books of 500 pages (1.05 kg/book) produced, used and disposed of in the USA, whereas Enroth (2009) studied books of 0.8 kg each produced, used and disposed of in Scandinavia. Kozak concluded that paper production, printing and personal transportation were the main factors influencing the total environmental impact of the paper book. In the Enroth study, paper production and printing were major issues; no personal transportation to buy the books was included.

Williams and Tagami (2003) studied the energy use of selling books in traditional and internet bookshops in Japan, considering sales, distribution, personal transportation and home energy use for internet purchasing (computer production and use; heating and lighting of one room). Their conclusions were that the differences between the two were not significant and that important issues were packaging, personal transportation and distribution. They mention the possibility of less wasted products, due to fewer returns of non-sold books, as an area that needs to be studied.

The sale and distribution of books are activities that have changed through increased use of the internet. Although some studies of the environmental impacts of books have been performed, several questions remain unanswered. A project was therefore initiated to study the potential environmental impact of books, comparing traditional paper books sold in traditional bookshops, traditional paper books sold via internet bookshops and e-books sold via internet bookshops and read on an e-book reader. The main aim of the part of the project reported in this paper was to analyse the environmental impacts of literary paper books and identify key issues that determine the magnitude of the impacts. A second aim was to study the environmental difference between a paper book bought in a traditional bookshop and through an internet bookshop. In addition, areas with a lack of data and major uncertainties were to be noted. In an accompanying paper, paper books are compared with e-books (Moberg et al. 2011). More information on the scope and the inventory data is given in Borggren and Moberg (2009) with appendices.

2 Materials and methods

2.1 Method

Life cycle assessment (LCA) is described in textbooks (e.g. Baumann and Tillman 2004), scientific papers (e.g. Finnveden et al. 2009) and an ISO standard (2006). The present study comprised a screening LCA in the sense that easily accessible data were used. The study used the LCA software tool SimaPro 7.1.8 (PRé Consultants 2008). As far as possible, data obtained from the Ecoinvent 2.0 database (Frischknecht et al. 2007a) as provided in SimaPro were used (PRé Consultants 2008). However, in several cases, general data were not available and in these cases, company- and site-specific data were used as approximations as described below and in more detail in Borggren and Moberg (2009). The data used were average data (not marginal) in line with an attributional LCA (Tillman 2000). For the impact assessment, CML impact assessment methods (Guinée et al. 2002) as provided in SimaPro 7.1.8 were used. Biotic carbon dioxide was excluded from the climate change impact assessment. The cumulative energy demand (Frischknecht et al. 2007a), as implemented in SimaPro, was calculated.

2.2 Scope of the LCA

2.2.1 Description of the book studied

Based on information from publishing house Bonnierförlagen (M. Lind, Bonnierförlagen, personal communication, October 2008 to May 2009), the average paper book defined for the study was a hardcover novel with dimensions 151×228 mm and a total weight of 0.6 kg. The inset consisted of 360 pages of 80 g/m^2 paper. Before and after the inset there were two times four pages (endpapers) of 115 g/m^2 paper. The hardcover was made from 1,230 g/m^2 cardboard and the soft cover of 130 g/m^2 paper. The paper book was printed in 3,000 copies and produced, bought and disposed of in Sweden. The functional unit of the book system studied was defined as “one book bought and read by one person”.

2.2.2 System studied

Editorial work Within the system boundaries, the life cycle started with the editorial work at the book publisher. The work of the author was not included in the system studied. The editorial work was accounted for as total electricity, heat and tap water used, as well as travel (only air travel figures were available) at the Bonnierförlagen during 2008 (M. Lind, Bonnierförlagen, personal communication, October 2008 to May 2009). Monetary allocation was made based on the share of total income from this specific book. These

company-specific data were used as an estimation of the environmental impact of the editorial work, as more detailed information was not available.

Paper production In parallel, the paper life cycle started with forestry followed by pulp and paper production. The data on pulp and paper production used reflect average European values (Hischier 2007); for the inset and endpapers, data on wood-free uncoated paper was used; for the cover, wood-free coated and for the hard cover, core board data.

Printing The printing technique used was coldset offset printing. Since no average data for Swedish conditions were readily available, the data used for the printing process were site-specific data from a Swedish printing office. The printing processes at this printing office were more efficient than average European conditions and also regarded as being more energy-efficient than average Swedish conditions (A. Linder, Scandbook AB, personal communication, January and May 2009). The energy data was limited to the electricity use for printing and district heating for the printing localities. Other electricity use for ventilation, office work, etc. was not included due to data availability. The printing office was also where the parts of the book were assembled to form the defined paper book. The transportation of the paper to the printing office was included here.

Distribution Company-specific data from the internet bookshop Adlibris (P. Svärdson, personal communication, 2009), Bonnierförlagen (M. Lind, personal communication, October 2008 to May 2009) and the logistics company Schenker (F. Goldbeck-Löwe, personal communication, April 2009) were used for the distribution of books. From the printing office, the book was transported by lorry to a central warehouse, from where it was then distributed, using different sizes of lorries (data from Ecoinvent 2.0 as described in Borggren and Moberg 2009), to possible bookshops all over Sweden. The book bought from an internet bookshop was transported from the same central warehouse to an internet bookshop warehouse and then distributed to possible package pick-up points all over Sweden. The data were based on total tonne–kilometres and total weight for the distribution of all books bought from Adlibris during 2008 (F. Goldbeck-Löwe, Schenker, personal communication, 2009). These data were adjusted to include 0.05% return of the books bought from an internet bookshop (P. Svärdson, Adlibris, personal communication, 2009). The figures were also adjusted to match the distribution of books bought at a traditional bookshop with 14% returns (H. Rudels, Bonnierförlagen, personal communication, March 2009 and P. Svärdson, Adlibris, personal communication October 2008 to May 2009). The distribution of books to traditional bookshops demands less packaging than distribution via internet bookshops.

Internet use Buying a book from an internet bookshop was assumed to require a desktop computer and access to the internet. The time spent and size of data used at the internet bookshop to buy the book were approximated to 7 min and 0.7 MB, respectively. Use of the internet was covered as energy use of the modem and of the hubs, routers and switches of the internet infrastructure. Rough figures provided by Taylor and Koomey (2008) illustrate 2006 conditions in the USA; these were halved to estimate the energy use per GB in 2008 (J. Malmodin, Ericsson Research, personal communication, April 2009). Production of cables and carbon dioxide emissions related to construction work and dismantling were included (D. Lundén, TeliaSonera, personal communication, April 2009). The operation and production of the desktop computer used were included. The impact of production was allocated based on the time of use (Borggren and Moberg 2009).

Electricity The electricity used was Swedish average electricity mix for processes occurring in Sweden (Frischknecht et al. 2007b). For general processes from the Ecoinvent database, the electricity mix given in the data was used.

Traditional bookshop The traditional bookshop's contribution to the environmental impact of a paper book consisted of total energy use at the bookshop allocated to the paper book, using the paper book's monetary share of the bookshop's total income (B. Kröjtz, Bokia Mora, personal communication, May 2009).

Paper book user The paper book user can either buy the book from a traditional bookshop or from an internet bookshop. The assumption for personal transport was that 2 km with a passenger car was allocated to the purchase of the paper book. General data on personal transport by car from Ecoinvent 2.0 were used in both cases. The same data and distance, but to a pick-up point, were assumed for the book bought via the internet. There are other possibilities as well. Company-specific information on the distribution from an internet bookshop (P. Svärdson, Adlibris, personal communication, 2009) can give an illustration: 40% of the books are delivered to a pick-up point, while 30% are delivered by economy class mail and 30% by first class mail directly to the end-user. The two latter options were tested in sensitivity analyses.

Waste treatment of paper books In this study, each book was assumed to only be read by one person and then

disposed of through incineration with energy recovery (Sveriges avfallsportal 2009). Any books not sold at the bookshop were assumed to be returned to the central warehouse and from there sent to recycling with material recovery, unless sent out to the bookshop again. The return rate for traditional bookshops was set at 14% and for internet bookshops 0.5% (H. Rudels, Bonnierförlagen, personal communication, March 2009 and P. Svärdson, Adlibris, personal communication, October 2008 to May 2009).

3 Results

3.1 Environmental impacts of a paper book

Figure 1 shows the relative contribution of the different life cycle phases of the paper book distributed via a traditional bookshop. Absolute values for the whole system are given in Table 1. Production of paper and the buyer using a car for going to and from the bookshop caused the majority of the potential non-toxic environmental impacts. When toxicological impacts were considered, paper production was still a major contributor. However, waste management caused a major fraction of the total marine aquatic ecotoxicity, as well as human toxicity. On the other hand, the waste management led to a substantial reduction in the total freshwater aquatic ecotoxicity. It should be noted that toxicological impact assessments are uncertain and should be interpreted cautiously.

Resource use was assessed using abiotic depletion as well as cumulative energy demand. “Paper production” and “book user transport” resulted in the largest abiotic resource depletion. Paper production and energy use in the bookshop gave rise to the largest cumulative energy demand. For these two life cycle phases, the non-renewable part was of similar magnitude. The bookshop environmental impact was due only to electricity production and thus depended on the geographical location. Swedish electricity is mainly based on hydro and nuclear power.

3.2 Buying the book in a traditional bookshop vs an internet bookshop

Figure 2 shows the relative contribution of the different life cycle phases of the paper book distributed via an internet bookshop. Absolute values for the whole system are given in Table 1. The pattern for the paper book bought at an internet bookshop was similar to that for the paper book bought at a traditional bookshop. One difference regarding the main contribution was that the impact of the traditional bookshop was no longer present and that the internet bookshop gave rise to considerably less impact. However, the data on energy use in the traditional bookshop were based on energy use in one specific shop and were monetarily allocated. Thus, there are large uncertainties regarding the magnitude of this difference.

Another difference between the system with a traditional bookshop and the system with the internet bookshop was that there were more returns of books from the traditional bookshop. For every book sold, there were thus more books produced for the traditional bookshop. The environmental impacts of the paper, printing and distribution of the unsold books were allocated to the books sold. As modelled here, the distribution impact of the book was higher for the internet bookshop system, partly due to the books being transported via the internet bookshop warehouse before

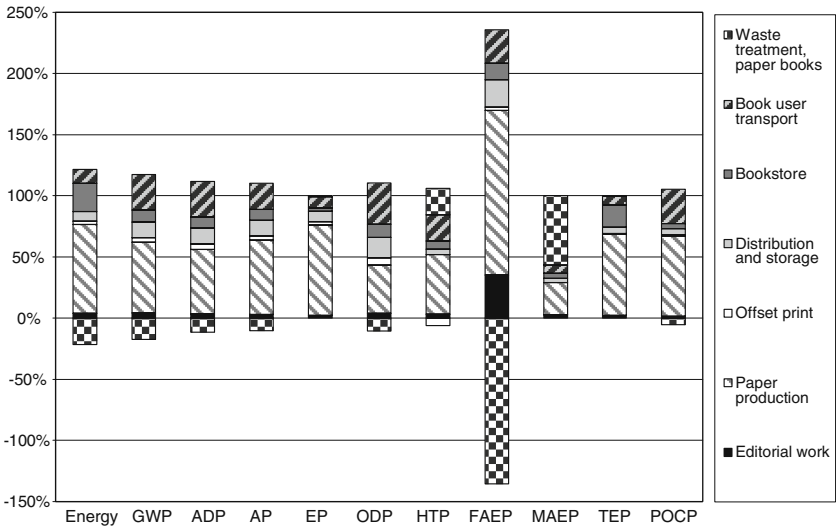

Fig. 1 Potential environmental impact of a paper book distributed via a traditional bookshop. Impact category abbreviations are listed in Table 1

Table 1 Life cycle impacts of a paper book distributed via a traditional bookshop and via an internet bookshop

Impact category	Unit	Book, traditional bookshop	Book, internet bookshop
Energy	MJ eq	56	40
GWP	kg CO_2 eq	1.3	1.1
ADP	kg Sb eq	0.0085	0.0074
AP	kg SO_2 eq	0.0057	0.0049
EP	kg PO_4 eq	0.0018	0.0016
ODP	kg CFC-11 eq	1.4E-07	1.2E-07
HTP	kg 1.4-DB eq	0.86	0.78
FAEP	kg 1.4-DB eq	0.074	0.061
MAEP	kg 1.4-DB eq	526	503
TEP	kg 1.4-DB eq	0.012	0.0081
POCP	kg C_2H_4	5.2E-04	4.5E-04

Energy cumulative energy demand, *GWP* global warming potential, *ADP* abiotic depletion, *AP* acidification potential, *EP* eutrophication potential, *ODP* ozone depletion potential, *FAEP* freshwater aquatic ecotoxicity potential, *HTP* human toxicity potential, *MAEP* marine aquatic ecotoxicity potential, *TEP* terrestrial ecotoxicity potential, *POCP* photochemical ozone creation potential

being distributed to the pick-up point and partly to extra packaging around the books.

Figure 3 compares the relative potential environmental impact of the two bookshop alternatives. From this it can be seen that for all impact categories, the paper book bought at an internet bookshop had a slightly lower environmental impact.

3.3 What if different paper was used?

Books are mainly printed on uncoated wood-free or wood-containing paper. In this study, uncoated wood-free paper was assumed, based on average European data (Hischier 2007). As paper production is a major part of the total environmental impact of paper books, a sensitivity analysis was performed to consider the effect of using wood-containing paper instead. As there were no data of this kind available in the database, data concerning a specific paper from a Swedish mill were used. Information from the environmental product declaration (Holmen 2008) was complemented with information from the same source about transportation of supply material to the paper mill (R. Nilsson, Holmen Paper, transport data as provided by A Berglund, Holmen Paper, personal communication, March 2009). Some data were lacking for pulp and paper production (for example forestry was not included) compared with the general European paper and thus these results are uncertain. However, the environmental impact of the paper book was decreased when the alternative paper data were used, as shown in Fig. 4.

3.4 Different distribution alternatives

In the study, rough assumptions were made to illustrate the possible distribution of paper books to consumers via traditional bookshops or internet bookshop facilities. There is no thorough information describing the average distribution of books in Sweden. The assumptions on distribution were varied in sensitivity analyses in order to consider the possibility of ordering books via the internet which were then delivered via the postal service to the customer's home (Fig. 5). In addition, the behaviour of the consumer was varied considering whether the car was used to buy books in the bookshop or pick-up books at the pick-up point. In the base scenario, 2 km with a passenger car was allocated to one book (Fig. 6). This may illustrate actually driving

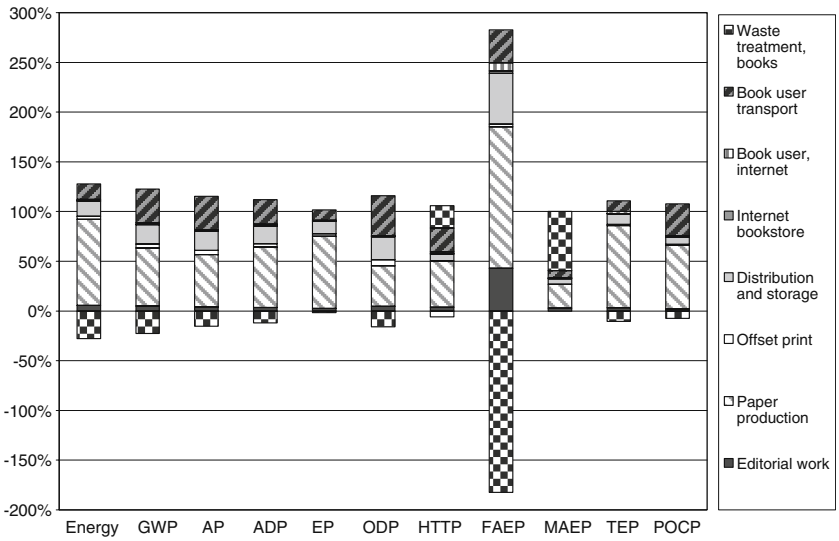

Fig. 2 Potential environmental impact of a paper book distributed via an internet bookshop. Impact category abbreviations are listed in Table 1

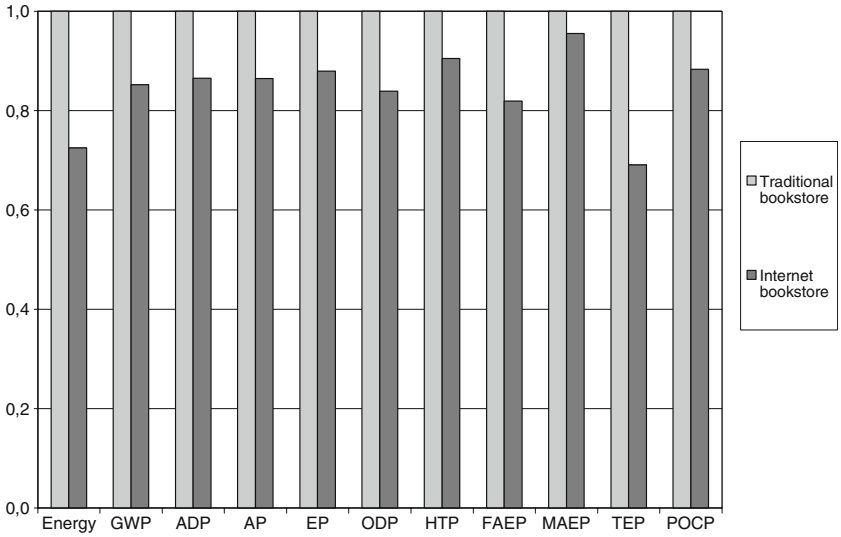

Fig. 3 Comparison of potential environmental impact between a paper book bought at a traditional bookshop and a paper book bought at an internet bookshop. Impact category abbreviations are listed in Table 1

2 km specifically to collect one book, or it may illustrate a longer drive where other errands are carried out and part of the drive (2 km) is specifically allocated to the book. In the sensitivity analysis, a longer distance was studied, 10 km allocated to the book, and also the case where the consumer does not use a car at all, but, e.g. walks.

The sensitivity variations of the distribution were only performed for the Global Warming Potential and were based on data from Posten Meddelande AB (2007a, b), replacing the distribution data from Schenker and the travel by passenger car to the pick-up point. The results showed that buying a book from an internet bookshop and walking to pick it up had about 56% of the impact of buying the book at a traditional bookshop. The results were similar (54%) for the book delivered to the end consumer by economy mail (see Fig. 5).

4 Discussion

In addition to paper production, consumer-related activities were major contributors to the total environmental impact of the paper books in this study. The buyer of a book from a traditional bookshop could significantly influence the total impact by choosing to walk to the bookshop or to combine the trip with several other activities to decrease the impact of the travel per activity performed. Urban and rural planners could support environmental behaviour, for instance by providing physical structures that make walking easier. In addition, the energy use at the traditional bookshop may form an important part of the total impact, especially if the electricity used gives rise to more environmental impact than the Swedish mix. It is interesting to note that the storage of a book at home, which was not considered in the study, would account for an energy

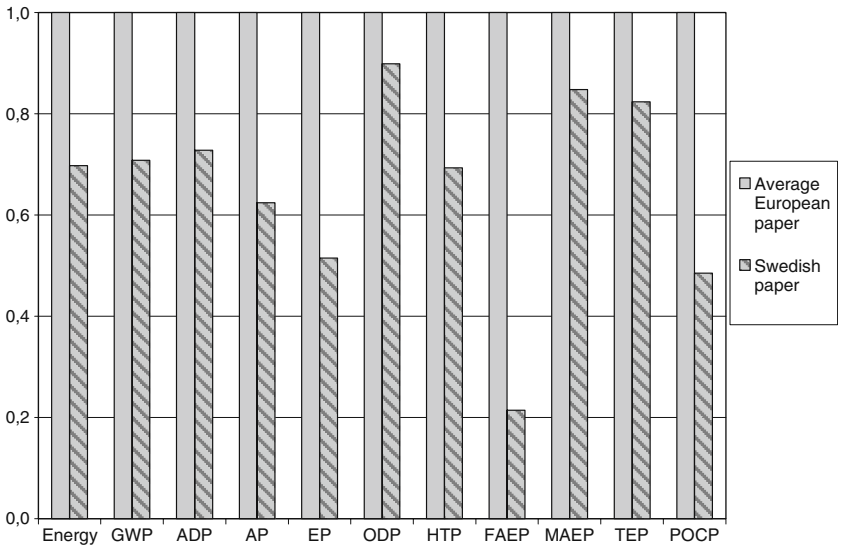

Fig. 4 Variations in potential impact through altering the paper used for the paper book distributed via a traditional bookshop. Impact category abbreviations are listed in Table 1

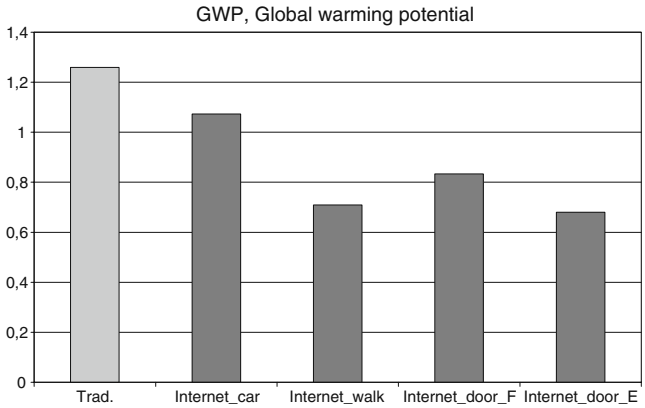

Fig. 5 Variations in potential climate change impact through altering the distribution system. Distribution via traditional bookshop (Trad); distribution via internet bookshop and pick-up point using a car to pick up the book (Internet_car); distribution via internet bookshop and pick-up point and walking or cycling to pick-up the book (Internet_walk); distribution via internet bookshop delivering the book to the door with first class mail (Internet_door_F); distribution via internet bookshop delivering the book to the door with economy class mail (Internet_door_E)

use which is roughly 80% of that of the bookshop allocated to the book in this study. This rough estimation was based on an energy use of 150 kWh/m^2 per home and year (SCB 2007) and 10 years of storage in a six-shelf bookcase. Storing books for several years could also have implications on the environmental impact through carbon storage in the books.

Kozak (2003) and Enroth (2009) came to the conclusion that paper production and book printing were the main issues for the printed scholarly books they studied. In addition, personal transportation for buying books contributed significantly to the overall environmental in the Kozak (2003) study. Paper production and personal transportation were in line with the results presented here. However, in our study, the printing was of minor importance. The data for the printing process did not cover electricity use for other processes than printing, e.g. ventilation, office work, etc. was not covered. However, even a doubling of the electricity use within the printing process would give similar overall results. The low impact related to the printing process may be a consequence of an efficient printing technique, Swedish electricity mix and the fact that the books studied here were only text in black and white. It was actually the transport of paper to the printing house that caused the main environmental impact of printing in many impact categories (not shown here). This indicates that the choice of printing process and the location of the printing house may be important.

Many studies on printed media have shown that paper production forms a major part of the total environmental impact, between 30–70% (Enroth 2006). However, the personal transportation to buy a book is not always considered in the defined product systems and the current study, like Kozak (2003), illustrated that this can be of importance. It could be interesting to study the bookshop's environmental impact in more detail.

There is no way to state the environmental impact of "a book", as the variation is large. The environmental impact will vary depending on technical issues such as the number of pages, text only or pictures, type of printing technique and location of pulp and paper mills and printing offices. Behavioural issues may also affect the resulting impact, since if the book is read several times (by one or more readers) the impact per benefit will decrease substantially, which is important when comparing it with an electronic book (Moberg et al. 2011) or other entertainment. Nevertheless, it can be interesting to consider the order of magnitude of impact. For example, the assessment by Kozak (2003) produced a value of 6.3 kg CO_2eq/kg book (whereof 55% pulp and paper) and 0.03 kg SO_2eq/kg book in terms of acidification. Enroth (2009) arrived at a figure

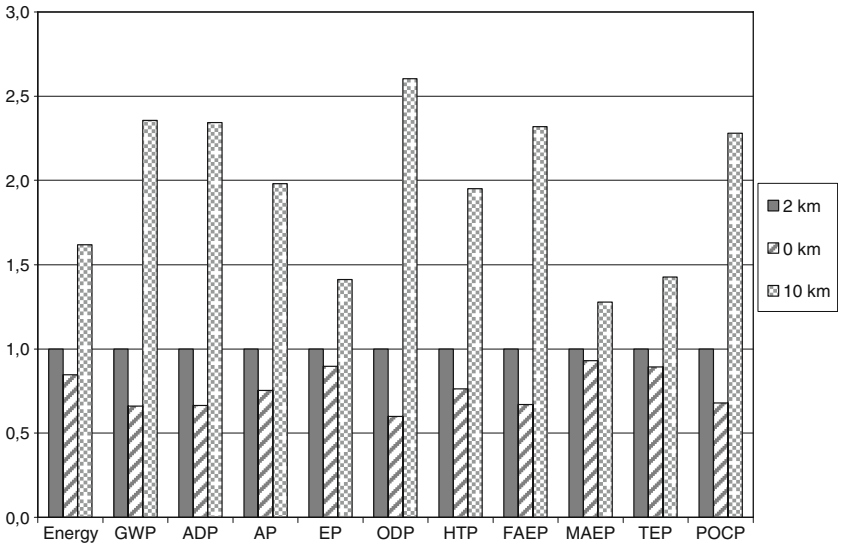

Fig. 6 Variations in potential impact through altering the means used for picking up the book at a pick-up point. The assumptions are 0 km, 2 km and 10 km with a passenger car allocated to collection of the book, respectively. Impact category abbreviations are listed in Table 1

of around 0.6 kg CO_2/kg book, mainly from pulp and paper production (60–50%). Our study resulted in a lower environmental impact per kilogram book than Kozak and higher than Enroth. The current study arrived at 2.1 kg CO_2eq/kg book and 0.009 kg SO_2eq/kg book (note the per kilogram book units to facilitate comparison). Compared with our study, paper production in the Enroth study had less climate impact and the bookshop and personal transportation were not covered. As the Kozak study was based on U.S. conditions, this gave rise to considerable differences in terms of paper production, printing energy use, etc.

The average book studied here was a hardback novel, and a study on paperback books would probably show a lower impact as the total amount of paper used is less. The environmental impact is closely related to the number of pages and thicker books have a higher environmental impact, but the benefit/value is perhaps sometimes related to the number of pages. In addition, the environmental impact per book will significantly decrease as the number of readers increases. The assumption of only one reader per book made in this study is conservative. The geographical scope of the study influenced the results, as regions with different electricity mixes will result in a different environmental impact.

The paper book bought from a traditional bookstore and an internet bookshop had similar environmental impact. However, with the assumptions made in this study, the impact for all impact categories was slightly preferable from an environmental perspective for the book bought from an internet bookshop. The benefits were related to not needing a traditional bookshop and to fewer returns. The energy use of the traditional bookshop is uncertain, but it can be assumed that the energy use is higher than that related to the internet bookshop. Regarding the difference in returns, the environmental impact related to this mainly depends on the amount of books produced that are not sold and read, rather than the extra distribution needed. The magnitude of the difference between the traditional and internet bookshop can thus be discussed. Will a certain amount of books be produced in any case? This study assumed that as more books were ordered by the traditional bookshops than would actually be sold, more books than necessary were printed. The amount of books printed to satisfy the orders of the internet bookshops is not as predictable and of course some extra books may be printed as the publisher estimates the orders to come from these stores. Producing fewer books that end up being wasted is still an important part of the environmental performance of the printed book industry and the actual benefit of internet bookshops in this respect is uncertain. Regarding the distribution as such, internet selling may result in longer total transport from central storage to the geographical location of the buyer, since extra transport may be needed as the books are distributed via an internet bookshop warehouse.

The study was a screening LCA, and there are limitations regarding the data used. The intention was to study an average hardback paper book in Sweden. However, general average data were not available in several cases and site-specific data were used. Larsen et al. (2006) emphasise the need to cover all printing chemicals and toxic emissions when assessing printed media. This is of course true for all chemicals and toxic emissions of all processes. However, within the scope of this study gathering of new information was limited and thus chemicals and toxic emissions were covered to a limited extent. In addition, impacts related to land use, which is relevant for forestry, were not included.

The type of paper used is important, as paper production was shown here to be a major contributor to the total potential impact. In this study, we tested two different kinds of paper, wood-free and wood-containing, but the data set for the latter was less comprehensive, making the comparison uncertain. The more environmentally beneficial outcome of using the wood-containing paper may be due to the less comprehensive data, the different electricity mix used (UCTE or Swedish) or the paper production actually generating less environmental impact. More detailed studies would be needed to draw firm conclusions.

It was not possible to study the distribution of books in detail and estimations had to be used. However, the results showed that personal transportation can be a significant contributor to the total environmental impact. When the distance allocated to one book bought was 2 km, personal transportation was more important than goods transport in all impact categories except eutrophication. Concerning the travel habits of the consumer, the allocation of distance travelled for buying a book may be discussed. Here, we made a rough assumption, which was tested in a sensitivity analysis. We did not know whether the consumer travel is longer or shorter if the book is bought via an internet bookshop, but it can be argued that pick-up points are often closer to the consumer than the bookshop. If this is so and the personal transportation differs because of the way the book is bought, this would be an important factor influencing the comparison. A study of the Swedish Postal Service concerning its reorganisation from post office collection points to service points showed only minor changes in travel pattern (Smederöd 2003). The distance to the service points was shorter, but there was no clear link to decreased environmental impact. Here we did not make a distinction between personal transport to the bookshop and to the pick-up point, but allocated the same transport distance to the books studied. The potential difference is hard to determine, e.g. even though a pick-up point may be more conveniently located, it may be that the trip there is less often combined with other errands than the trip made partly to buy a book in the traditional bookshop. The results

show that personal travel can influence the total environmental impact of the book product life cycle, even though the average impact cannot be established.

Buying the paper book via an internet bookshop and getting it delivered to the door by economy class mail or walking to the pick-up point resulted in the lowest potential global warming impact of the paper book. Paper books can also contribute to carbon storage if they are saved for a long period.

It can also be noted that the environmental impacts of books are fairly limited compared with those of, e.g. transportation. This is illustrated in Fig. 6 where it can be noted that driving a car 10 km causes approximately three times as great a contribution to global warming as the rest of the book life cycle.

5 Conclusions

The main environmental impact of paper books results from producing the paper. Choice of paper can influence the total environmental impact, as an efficient process will give rise to less impact. The location of the paper mill can influence the impact depending on the electricity mix used in production. To fairly compare different types of paper, comparable data sets with the same system boundaries and detail need to be used.

This study showed that personal transportation can be a significant contributor to the total environmental impact of paper books. It also indicated that the distribution of the books can be important and that buying a paper book from an internet bookshop, having it delivered by economy mail to the home or walking to pick it up could be the environmentally preferable way to buy a paper book. The differences in potential environmental impacts of the paper book bought from a traditional and an internet bookshop respectively were small in relation to their uncertainty and furthermore dependent on consumer behaviour.

The study highlights the importance of the user and their practices for the overall environmental impact. For example, the impact per book read can be significantly decreased by sharing books with others.

6 Recommendations and perspectives

The results of this study suggest that the environmental impact of paper books could be reduced through a deliberate choice of paper when producing the books, keeping the returns of books low and minimising consumer travel related to the buying of books. Internet bookshops can reduce the overall impact, as the energy use of traditional bookshops is not part of that system. However, the distribution needs to be efficiently managed. Ultimately, sharing books will reduce the environmental impact per benefit.

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